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Fusarium Seed Piece Decay of Potato on Long Island and Its Control

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Potato Field on Long Island Showing the Effect of Severe Fusarium Seed Piece Decay on Stand. Photographed May 21, 1945.

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ABSTRACT

FUSARIUM seed piece decay was found to be the cause of many poor stands of potatoes grown on Long Island. *Fusarium coeruleum* and *F. sambucinum* f. *6* were determined to be the fungi chiefly responsible. In some instances of severe infection, the stand was as low as 10 per cent.

It was determined that these pathogens may be present on seed stock sent in from all chief seed sources. Irish Cobbler, Green Mountain, and Chippewa were found to be affected.

Isolations made from storage rot of tubers showed that the organism causing the rot was not necessarily the one causing seed piece decay.

Fusarium seed piece decay takes the form of a dry rot and never becomes soft unless invaded by other organisms. Invaded tissue is brown in color and infection is not always noticeable on the cut surface.

Detailed descriptions are given for *F. coeruleum* and *F. sambucinum* f. *6*, the two organisms thus far found to be chiefly responsible for seed piece decay, and for *F. solani* v. *striatum*, which occasionally has been isolated and which will produce a storage rot but no serious seed piece decay.

The fusaria gain entrance through wounds. They are unable to penetrate the uninjured surface of a potato tuber or the properly cured cut surface of a seed piece.

It has been shown that spores of the pathogenic fusaria may be carried on soil adhering to the surface of healthy tubers and in soil adhering to containers.

Seed treatment by the instant dip method, using either yellow oxide of mercury (1–30) or Semesan Bel (1–7½), is effective in controlling seed piece decay. Treatment of seed pieces after cutting is not recommended.

Containers in which untreated potatoes were shipped or stored may carry the disease organisms. They should be treated either with steam, by boiling, or by dipping in the solutions used for treating seed potatoes if they are to be used for storing treated seed or seed pieces.

Bulletin No. 721

FUSARIUM SEED PIECE DECAY OF POTATO ON LONG ISLAND AND ITS CONTROL

H. S. CUNNINGHAM and OTTO A. REINKING

INTRODUCTION

POTATOES constitute the major crop grown on Long Island. Some 60,000 acres are planted to potatoes each year in Suffolk County and an additional 10,000 acres in Nassau County. Estimates of the cost of growing and marketing an acre of potatoes on Long Island vary greatly, but $225 per acre is probably a fair figure. On this basis the industry represents an investment of some $15,750,000 annually. Of this amount about $3,500,000 is expended in the purchase of seed, virtually all of which comes from seed-producing areas in the northern part of the State, Maine, and Canada.

The loss in stand because of seed piece decay may vary from 10 per cent to almost a complete failure (frontispiece). Not only is the stand affected, but many of the plants which do emerge are weak and fail to make a normal growth and this seriously affects the yield. Where the stand is seriously affected the area involved must be replanted or planted to some other crop. Replanting of potatoes is both costly and unsatisfactory, and usually by the time the grower realizes the situation, it is too late to replant with the expectation of getting a good crop.

During the past 15 years numerous complaints have been received of poor stands due to decaying seed pieces. Various factors were assigned as causes, such as fertilizer injury and fungous infection. Studies started in 1942 indicated that all injury was not caused by fertilizer and that a fungous rot may be one of the primary factors. A species of Fusarium was isolated from diseased seed pieces which, by inoculation and re-isolation, was shown to cause seed piece decay. Further studies have shown that at least two species of Fusarium may be responsible for seed piece decay on Long Island and that in most instances one or the other of these organisms is involved in the first stage of decay. These studies take into consideration primarily the seed piece decay that takes place in the field after planting and not the ordinary dry storage rots.

The object of the present studies was to determine the main cause of seed piece decay under Long Island conditions and to determine control measures. The studies were conducted from 1942 through 1945 primarily in potato fields of Suffolk and Nassau counties. The experimental plots were located at Riverhead, Long Island. Fungous studies and determinations were made of cultures isolated from seed pieces taken from potato fields in these regions and from decayed tubers shipped from Canada, Maine, and northern New York seed potato areas.

SYMPTOMS OF SEED PIECE DECAY

The decay of potato seed pieces due to Fusarium is in the form of a dry rot. The diseased tissues never become soft or mushy unless, as frequently occurs in the field, they are invaded by other organisms. The first noticeable evidence of infection is usually a small sunken area on the cut surface (Fig. 1) beneath which the tissue will be brownish in color. Once the tissues become invaded the organism will continue to grow until the entire seed piece is affected and later, under dry conditions, becomes mummified and extremely hard in texture (Fig. 2). If the seed pieces are kept under conditions of high humidity, the cut surface will be covered with a whitish mass of mycelium producing spores in abundance. Under certain conditions, as yet undetermined, there may be no noticeable evidence of in-

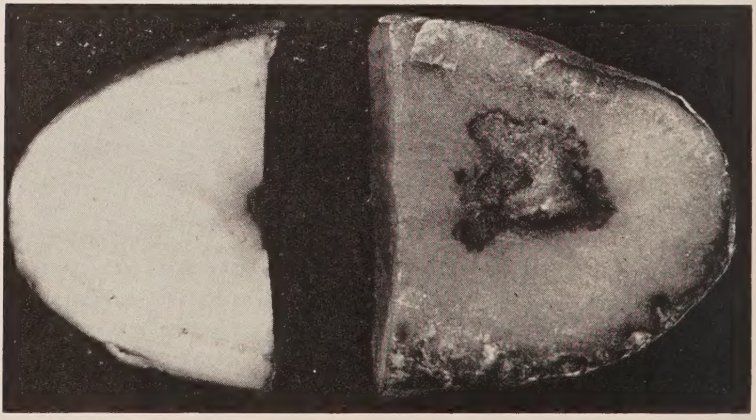

FIG. 1.—EARLY STAGES OF FUSARIUM SEED PIECE DECAY.
Seed pieces inoculated with *F. coeruleum*.

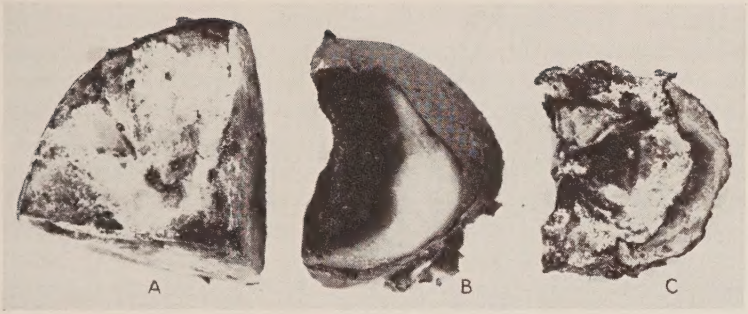

FIG. 2.—POTATO SEED PIECES SHOWING ADVANCED STAGES OF FUSARIUM SEED PIECE DECAY.

Pieces inoculated with *F. coeruleum*. A, spore masses on the surface of a partially decayed seed piece; B, partially decayed seed piece; C, completely decayed and mummified seed piece.

fection on the cut surface and it is only when the seed piece is cut that the brownish tissue beneath reveals that infection has taken place.

MATERIALS AND METHODS

Numerous isolations were made from both tubers and seed pieces. In the case of seed pieces, these were made from samples taken before planting from lots in storage and from seed pieces taken from the soil some time after they had been planted. Such isolations were made from Irish Cobbler, Green Mountain, and Chippewa, and in most cases yielded a pure culture of one of the two species of Fusarium referred to in this bulletin as causing seed piece decay.

For all inoculation work, both in the laboratory and for field experiments, pure cultures of the chief pathogens, *Fusarium coeruleum* and *F. sambucinum* f. *6*, were used. In addition to these *F. solani* v. *striatum* shown to be capable of producing a tuber rot, but not serious seed piece decay, was used primarily as a check on *F. coeruleum*. Several methods of inoculation were followed to establish the pathogenicity of these fungi in laboratory tests. Inoculations were made with a drop of spore suspension placed on the cut surface of a seed piece or on the bruised area of a tuber. Dipping the freshly cut seed pieces, or freshly bruised tubers, in a spore suspension was another method used. For field work the whole tubers were inoculated either by mixing them with portions of tubers carrying a heavy mass of spores or by using a spray gun and applying a spore

suspension. This was done with seed pieces as well as tubers. Following inoculation the various treatments for control were applied, after which the tubers were cut and the seed pieces held in storage under conditions deemed favorable for infection. Field plantings were made either by hand or by an assisted feed planter. Single-row 25-foot plots were used with eight replications. Stand counts were made and wherever practicable seed pieces were examined and isolations made. The tubers were lifted after the plants had matured and yield data recorded as total, No. 1, No. 2, and culls. The No. 1 tubers were those passing over a 1 15/16-inch standard grader chain and the No. 2 tubers those passing over a 1½-inch chain.

EXPERIMENTS AND RESULTS

PREVALENCE OF THE DISEASE

In 1942, 10 cases of seed piece decay were investigated and found to be caused by *Fusarium sambucinum* f. *6*. The total area involved was 225 acres and the percentage of infected seed pieces varied from 5 in some fields to 70 in others. In some instances the stand was as low as 10 per cent, while in others it was as high as 90 per cent. A good stand was not always associated with a low percentage of infection of seed pieces. Many fields showing a high percentage of infected seed pieces produced a good stand, but the plants produced from these infected pieces were usually smaller and weaker than plants from healthy seed pieces.

In 1943, 15 cases totaling 250 acres were investigated, all of which were caused by *F. sambucinum* f. *6*. Of 25 cases reported in 1944 only 10 were caused by fusaria with 300 acres affected. In two instances *F. solani* v. *striatum* was isolated, while *F. sambucinum* f. *6* and *F. coeruleum* were found in others. In 1945, 35 cases of seed piece decay were reported all of which were caused by fusaria with a total of 1,000 acres affected. On examination, the causal organism, in most instances, was found to be *F. coeruleum*, altho *F. sambucinum* f. *6* also was found. The cases reported were widely scattered in both Suffolk and Nassau counties and in several instances in 1945 involved 50 acres on which the stand was 10 per cent or less.

ISOLATIONS MADE FROM DECAYING SEED PIECES IN THE FIELD

In numerous instances in 1942 and 1943, *Fusarium sambucinum* f. *6* was consistently isolated from decaying seed pieces taken from fields. The pathogenicity of this organism was proved (Fig. 3).

FIG. 3.—SECTION THRU A POTATO TUBER SHOWING FUSARIUM ROT.
Tuber inoculated with *F. sambucinum* f. *6*.

During these preliminary studies, it was thought that seed piece decay on Long Island was caused by this single species. In 1944, the picture was somewhat different as isolations from diseased seed pieces yielded other species of Fusarium. In that season, altho *F. sambucinum* f. *6* was found, it was by no means the only species involved. In fact some of the worst cases on record were found to be caused by *F. coeruleum*. Similar results were obtained in the 1945 studies. Isolation data for the work done in 1945 are given in Table 1.

In most cases from 10 to 12 isolations were made from any given field. Of the 36 fields from which isolations were made, *F. sambucinum* f. *6* was found in 8, *F. coeruleum* in 28, and both species in 3. Inoculation experiments were conducted with these fusaria and their pathogenicity established.

ISOLATION AND PATHOGENICITY STUDIES ON SEED STOCKS

The 1942–45 experiments just discussed clearly showed that *Fusarium coeruleum* and *F. sambucinum* f. *6* were present in diseased seed pieces in Long Island plantings and that all isolates were pathogenic under test. In order to determine the distribution of these organisms in seed stocks, isolations were made from seed potatoes

TABLE 1.—ISOLATIONS MADE FROM DISEASED SEED PIECES COLLECTED IN POTATO FIELDS AFFECTED WITH SEED PIECE DECAY IN 1945.

SEED SOURCE AND VARIETY	NUMBER OF ISOLATIONS OF	
	F. coeruleum	*F. sambucinum* f. *6*
New York:		
Irish Cobbler	6	2
Green Mountain	10	2
Maine:		
Irish Cobbler	2	1
Green Mountain	3	1
Chippewa	1	—
Minnesota:		
Irish Cobbler	1	—
New Brunswick, Canada:		
Irish Cobbler	1	—
Prince Edward Island, Canada:		
Irish Cobbler	2	1
Green Mountain	2	1

shipped to Long Island from various sources. The results of these isolations and pathogenicity studies are presented in Table 2.

Isolations showed that the two seed piece decay organisms, *Fusarium coeruleum* and *F. sambucinum* f. *6*, were present on seed stock shipped in from northern New York, Maine, Prince Edward Island, and Minnesota, the chief sources of seed. All strains of these organisms were shown to be capable of producing seed piece decay. *F. solani* v. *striatum* isolated from New York potatoes was capable of producing a rot, but in tests discussed more fully under the section on control, did not readily produce seed piece decay. The following fusaria, nonpathogenic insofar as seed piece decay is concerned, were studied from various sources: *F. solani* (strain), *F. oxysporum* (strain), *F. culmorum*, and *F. avenaceum*.

ISOLATIONS FROM STORAGE ROT OF POTATOES

During the course of these studies, especially in 1944–45, various fusaria isolated from storage rot of tubers were submitted for determination by Dr. K. H. Fernow and Dr. M. F. Barrus of the Cornell University Agricultural Experiment Station, Ithaca, N. Y., and by Dr. Donald Folsom of the University of Maine Agricultural Experiment Station. The results of these studies showed that *Fusarium sambucinum* f. *6* was by far the most prevalent organism. Isolations made by the writers in 1945 from a lot of storage potatoes from the Geneva, N. Y., region resulted in obtaining only pure

TABLE 2.—DISTRIBUTION OF FUSARIA CAUSING SEED PIECE DECAY BASED ON ISOLATIONS AND PATHOGENICITY STUDIES.

ORGANISM	SOURCE OF SEED POTATOES	POTATO VARIETY	YEAR ISOLATED	PATHOGENICITY
F. coeruleum	Lake Placid, N. Y.*	Green Mountain	1944	Produced seed piece decay
F. coeruleum	Baldwinsville, N. Y.	Chippewa	1944	Produced seed piece decay
F. coeruleum	Mapleton, Me.	Irish Cobbler	1944	Produced seed piece decay
F. coeruleum	Prince Edward Island	Green Mountain	1944	Produced seed piece decay
F. coeruleum	Minnesota	Irish Cobbler	1945	Produced seed piece decay
F. sambucinum f. *6*	Lake Placid, N. Y.	Green Mountain	1942	Produced seed piece decay
F. sambucinum f. *6*	Maine†	Sebago	1943	Produced seed piece decay
F. sambucinum f. *6*	Prince Edward Island	Irish Cobbler	1944	Produced seed piece decay
F. solani v. *striatum*	Lake Placid, N. Y.	Green Mountain	1944	Produced a tuber rot
F. solani v. *striatum*	Baldwinsville, N. Y.	Chippewa	1944	Produced a tuber rot
F. solani (strain)	New York‡	———	1942	Produced a tuber rot
F. oxysporum (strain)	Lake Placid, N. Y.	Green Mountain	1944	Nonpathogenic
F. oxysporum (strain)	Saranac Lake, N. Y.	Green Mountain	1944	Nonpathogenic
F. oxysporum (strain)	Mapleton, Me.	Irish Cobbler	1944	Nonpathogenic
F. culmorum	Lake Placid, N. Y.	Green Mountain	1944	Nonpathogenic
F. culmorum	Utica, N. Y.	Green Mountain	1944	Nonpathogenic
F. culmorum	Ft. Fairfield, Me.	Irish Cobbler	1944	Nonpathogenic
F. culmorum	New Brunswick, Canada	Irish Cobbler	1943	Nonpathogenic
F. avenaceum	Maine†	———	1943	Nonpathogenic

*Also isolated from soil obtained under grader.
†Cultures sent in by Dr. Donald Folsom, Maine Agr. Exp. Station, Orono, Me.
‡Cultures submitted by Dr. K. H. Fernow, Cornell University, Ithaca, N. Y.

cultures of *F. sambucinum* f. *6*. Studies conducted by Cassel (2, 3)[1] in 1945 on dry rot of stored potatoes in New York indicated that *F. sambucinum* f. *6* was most commonly associated with the rot. Our isolations and inoculation studies made of seed piece decay on Long Island in 1945, discussed more fully under control experiments, showed that, while *F. sambucinum* f. *6* did cause rot, *F. coeruleum* was the most common and most virulent parasite. These studies would indicate that the organism most commonly associated with Fusarium dry rot in storage need not necessarily be the one chiefly responsible for seed piece decay in Long Island fields.

VARIETAL SUSCEPTIBILITY

No effort has yet been made to check on the susceptibility of potato varieties to the *Fusarium* spp. causing seed piece decay. The three varieties most commonly grown on Long Island are Green Mountain, Irish Cobbler, and Chippewa in the order of their importance. All three were found to be susceptible. Seed piece decay has been reported more frequently in fields of Green Mountain than in either of the other two varieties but this may well be because of the larger acreage planted to that variety. Observation and inoculation work in the laboratory would indicate that there is no difference in the susceptibility of these varieties.

It is felt that any difference there might be in susceptibility of varieties lies in the rapidity of wound cork formation. That there is a difference in the rapidity of wound cork formation under given conditions has been demonstrated by Weiss, *et al.* (9). These authors studied the rate of healing in six varieties of potatoes and listed them as follows in order of healing: Spaulding Rose, Irish Cobbler, Green Mountain, Bliss Triumph, Russet Rural, and White Rural. They also state that this was the order of their susceptibility to Fusarium rot. Artschwager (1) also notes a difference in the rapidity of wound cork formation between Irish Cobbler and Russet Rural.

Repeated attempts to obtain infection of seed pieces with *Fusarium coeruleum* and *F. sambucinum* f. *6* following wound cork formation were negative and indicates that wound cork is an effective barrier to invasion by fusaria. Irish Cobbler, Green Mountain, and Chippewa seem to be equally susceptible to Fusarium infection if inoculated seed pieces are kept under conditions unfavorable for wound cork formation.

[1]Figures in parenthesis refer to Literature Cited, page 32.

CAUSAL ORGANISMS

Descriptions of fusaria causing seed piece decay on Long Island.—Studies have shown that *Fusarium coeruleum* and *F. sambucinum* f *6* are primarily responsible for the fungous decay of seed pieces in the field. Since there may be some difficulty in their determination, the following descriptions of spore type and culture characters are presented. *Fusarium solani* v. *striatum*, which has been occasionally isolated and will cause a tuber rot, has been included mainly for comparison with the more virulent *F. coeruleum*.

Fusarium coeruleum (Lib.) Sacc.—Macroconidia in pionnotes 3 septate, 35.5×4.98 (29.5–41.5×4.5–5.6)μ; some 4–5 septate and few 0–2 and 6–7 septate conidia present; Chlamydospores terminal or intercalary, one- or two-celled, 9×8μ or 14×9μ, respectively. Sclerotia may be present in cultures. The macroconidia typically are only slightly curved and characteristically have an even diameter or are somewhat broader at the base (Fig. 4).

A sporulating culture on 2 per cent dextrose hard potato agar characteristically has scant white to cartridge buff (7) aerial mycelium and a dense mass of dusky green blue 1 and dusky orient blue pionnotes. Some cream color to sulfur yellow pionnotes may be present, but generally the pionnotes are colored green blue or blue from the stroma. Cultures not sporulating so well may have a more abundant white to cartridge buff mycelium in which is present a dark bluish glaucous to bluish gray green plectenchymatic stroma with the not-too-well-developed pionnotes mass of spores. The agar may be turned a dull Indian purple.

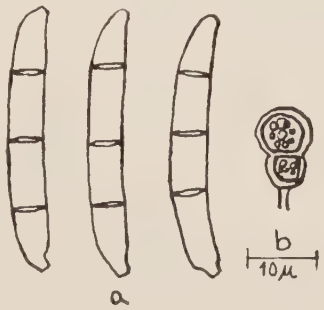

FIG. 4.—*F. coeruleum*. (a) MACROCONIDIA; (b) CHLAMYDOSPORE OR RESTING SPORE.

On 5 to 8 per cent dextrose hard potato agar, the scant mycelium and stroma are a deep purplish vinaceous or a Pompeian red to deep Corinthian red and Etruscan red, while the dense mass of pionnotes characteristically is a dark delft blue with dark vinaceous or dull Indian purple. The agar may be turned a dark Indian lake or brick red to ocher red. The development of the Pompeian red to deep Corinthian red and Etruscan red on the 5 to 8 per cent dextrose hard potato agar, along with other characteristics, seems to distinguish this organism from *F. solani* (strains) which may be encountered in isolations.

Growth on rice is characterized by a medium growth of white and pinkish vinaceous aerial mycelium and a dark vinaceous to light or deep Corinthian red stroma. Sclerotia covered with a white and deep Corinthian red mycelium may be abundant. The rice is frequently turned an Etruscan red in places.

Habitat: Isolated from potato seed piece decay on Long Island and from seed potatoes grown in northern New York, Maine, Prince Edward Island, Canada,

and Minnesota. Cause of seed piece decay in the field and dry rot of potatoes in storage.

Fusarium sambucinum Fuck. f. *6* Wr.—Macroconidia in pionnotes 3–5 septate rarely 6 and few 0–2 septate; 3-septate, 27.5×4.2 (22.5–31.0×3.5 5.0) μ; 5-septate, 36.0×4.8 (33.5–41.5×4.15–4.5) μ. Most sporulating strains produce primarily 3-septate spores, but occasionally strains are found in which the largest percentage of spores is 5-septate. Chlamydospores may be present, especially in spores, typically intercalary (Fig. 5). Dresden brown sclerotia may be formed.

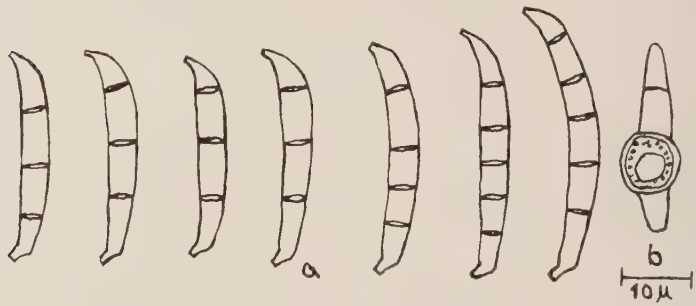

FIG. 5.—*F. sambucinum* f. *6*. (a) MACROCONIDIA; (b) CHLAMYDOSPORE OR RESTING SPORE DEVELOPED IN CONIDIUM.

A 2-week-old sporulating culture on a 2 per cent dextrose hard potato agar is characterized by a dense ochraceous salmon pionnotes growth with very scant production of a white aerial mycelium at the top of the slant. No carmine or red colors are produced in the mycelium. Some cultures may develop a light ochraceous buff or pinkish buff pionnotes, with a buckthorn brown, Dresden brown, and mummy brown stroma at the base. Older cultures generally are characterized by the darker colors. Dresden brown sclerotia may be developed.

Habitat: Isolated from potato seed piece decay on Long Island and from seed potatoes grown in northern New York, Maine, and Prince Edward Island. Cause of seed piece decay in the field and dry rot of potatoes in storage.

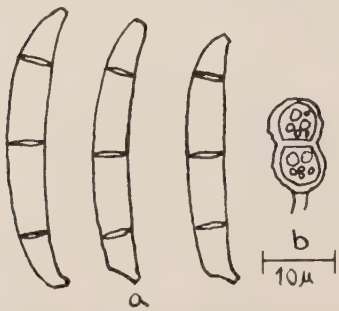

FIG. 6.—*F. solani* v. *striatum*. (a) MACROCONIDIA; (b) CHLAMYDOSPORE OR RESTING SPORE.

Fusarium solani (Mart.) App. et Wr. v. *striatum* (Sherb.) Wr.—Macroconidia in pionnotes 3-septate, 36.5×5.0 (32.0–41.5×4.5–5.5) μ; some 4–5 septate, few 0–2 and rarely 6-septate. The macroconidia are slightly curved and more or less pointed at both ends. Chlamydospores are terminal or intercalary and one- or two-celled, 9.0×8.0 (7.0–10.5×6.0–8.5) μ (Fig. 6). Sclerotia may be developed.

A sporulating culture on 2 per cent dextrose hard potato agar is characterized by a scant development of a car-

tridge buff to cream buff aerial mycelium and the development of a dense pionnotes mass of spores which may be cartridge buff, cream buff, or yellowish green to dusky blue green. The darker colors are developed from the stroma. The agar usually remains clear.

On a 5 to 8 per cent dextrose hard potato agar, the aerial mycelium is a cartridge buff or pinkish buff to cinnamon buff possibly with some purplish vinaceous. The color of the stroma and pionnotes remains about the same as on the 2 per cent dextrose agar or it may turn a honey yellow to an Isabella color, possibly with some dusky greenish blue 1. Since little change in color takes place on the 5 to 8 per cent dextrose agar, this characteristic may be an aid in distinguishing *F. solani* v. *striatum* from *F. coeruleum*.

On rice the aerial mycelium is cartridge buff and the stroma over the rice may be Eugenia red to Pompeian red with some Verona brown or Sayal brown. Cartridge buff sclerotia may develop. Seashell pink to salmon brown pionnotes may develop in places over the stroma.

Habitat: Isolated from potato seed piece decay on Long Island and from seed potatoes grown in northern New York. May produce a rot of tubers, but has not been found to be a main cause of seed piece decay.

This organism and related strains of *F. solani* were used in our tests primarily for comparison with the more virulent *F. coeruleum*.

Germination tests with spores at various temperatures.—Weiss, *et al.* (9) state that *Fusarium coeruleum* and *F. sulphureum* [*F. sambucinum* f. *6*] are able to initiate infection of potato tubers down to nearly the lowest temperature that may be safely employed in potato storage, but do not give the minimum temperature for germination of spores of the two species. Moore (5) in a study of the rate of growth of *F. coeruleum* found that the minimum temperature for germination of spores of this species is slightly below 5°C. In order to get more information on temperature in relation to spore germination, tests were made using hanging drop cultures in water. A summary of this work is given in Table 3.

Within the time limit of the experiment, *F. coeruleum* germinated at a lower temperature than did the other two species. This does not necessarily mean that spores of the other two species are not capable of germinating below 9°C, but it does indicate that spores of *F. coeruleum* will germinate much more rapidly at temperatures below 9°C than spores of the other two. In this work spores of *F. coeruleum* germinated at a somewhat lower temperature than the minimum reported by Moore (5), but it is quiet possible that this difference may be one of strains of the organism.

The fact that spores of *F. coeruleum* germinate more rapidy than do spores of the other two species studied may be of considerable importance in this problem and may well be a factor in the preva-

lence of *F. coeruleum* in causing seed piece decay in any given season. Slight differences in the temperature at which seed pieces are stored might allow *F. coeruleum* to invade the potato tissue before the other species would germinate and any sudden change to a higher temperature might establish a natural barrier to infection against the slower germinating species but too late to be effective against *F. coeruleum*.

TABLE 3.—INITIAL GERMINATION OF FUSARIUM SPORES IN HOURS AT VARIOUS TEMPERATURES.

TEMPERATURE, °C	NUMBER OF HOURS																	
	F. coeruleum						*F. sambucinum* f. *6*						*F. solani* v. *striatum*					
	9	15	22	32	40	48	9	15	22	32	40	48	9	15	22	32	40	48
3°	0	0	0	0	0	X*	0	0	0	0	0	0	0	0	0	0	0	0
6°	0	0	X	–	–	–	0	0	0	0	0	0	0	0	0	0	0	0
9°	X	–	–	–	–	–	0	0	0	0	0	X	0	0	0	0	0	X
12°	X	–	–	–	–	–	0	0	X	–	–	–	0	0	X	–	–	–
15°	X	–	–	–	–	–	0	X	–	–	–	–	X		–	–		–
18°	X	–	–	–	–	–	X	–	–	–	–	–	X			–	–	
21°	X	–	–	–	–	–	X	–	–	–	–	–	X	–	–	–	–	–

*X indicates time at which germination was first noted.

Rate of growth at various temperatures.—Temperature studies in relation to growth of *Fusarium discolor* v. *sulphureum* [*F. sambucinum* f. *6*] and *F. coeruleum* were made by Edson and Shapovalov (4) on plate cultures using potato agar without sugar. At the optimum temperature of 25°C, *F. discolor* v. *sulphureum* [*F. sambucinum* f. *6*] grew much faster than did *F. coeruleum* as indicated by the maximum diameter of the colony at the end of 7 days.

Using the same species as in the germination tests, growth experiments were made on plates using potato agar to which 2 per cent dextrose was added. A drop of spore suspension was placed in the center of each plate and the diameter of the colony measured in millimeters at daily intervals. The data are presented in Table 4.

Within the temperature range of this experiment the data given in Table 4 show that *F. sambucinum* f. *6* grows more rapidly in plate culture than do the other two species. There is no very marked difference between the rate of growth of *F. coeruleum* and *F. solani* v. *striatum*, but in general the former grew more rapidly at the lower temperatures and especially is this apparent at the end of the 8-day

TABLE 4.—GROWTH OF FUSARIA AT VARIOUS TEMPERATURES ON POTATO DEXTROSE AGAR PLATES AS INDICATED BY THE DIAMETER OF COLONIES IN MILLIMETERS.

TEMPERATURE, °C	NUMBER OF DAYS																									
	F. coeruleum							*F. sambucinum* f. *6*							*F. solani* v. *striatum*											
	2	3	4	5	6	7	8	2	3	4	5	6	7	8	2	3	4	5	6	7	8					
9°	0	0	0	7	12	13	20	0	0	7	12	20	25	33	0	0	0	0	6	7	8					
12°	0	0	6	12	15	27	34	0	8	15	22	35	43	54	0	6	7	8	13	16	18					
15°	0	12	17	25	37	45	55	5	21	36	51	80	90	–	6	12	16	22	32	38	44					
18°	5	12	18	24	37	46	55	10	23	37	54	80	90	–	8	13	18	25	33	40	44					
21°	7	15	22	32	41	46	60	18	36	59	80	90	–	–	11	19	28	37	57	69	80					

period. The data given are true insofar as the diameter of the colony is concerned, but the type of growth on agar plates of *F. coeruleum* and *F. solani* v. *striatum* is so different from that of *F. sambucinum* f. *6* that it is very questionable if diameter of colony is a fair measure of the comparative rate of growth of these three species. In general, *F. sambucinum* f. *6* produces a scanty growth of aerial mycelium and growth is mainly from the perimeter of the colony. This is in direct contrast to the other two species which have a tendency to produce a heavy mass of aerial mycelium and slower growth from the edge of the colony. It may be that there is little difference in rate of growth in relation to penetration of potato tissue.

Rate of growth of any given species of Fusarium capable of causing seed piece decay may be of considerable importance, especially in relation to varietal susceptibility and storage temperatures. As has already been noted, there is a difference between varieties in the rapidity with which wound cork is formed. While there is no data on this point, it would seem logical to suppose that the more rapid the growth of the organism the more likely it is to advance beyond the region of wound cork formation which, as will be shown later, provides a natural barrier against its advance.

SOURCE OF INFECTION

At first it was thought rotted tubers, infected with either *Fusarium coeruleum* or *F. sambucinum* f. *6*, might be wholly responsible for the subsequent infection of seed pieces.These diseased tubers do play a part, but our studies have shown that they are by no means the only factor responsible for seed piece infection.

In 1944, a survey of incoming seed stocks was made to determine to what extent, if any, diseased tubers were present. In all, 100 car lots were examined, either on the tracks or in storage. All suspicious tubers were taken to the laboratory and isolations made. The seed sources and varieties covered in this survey are given in Table 5.

TABLE 5.—NUMBER OF CARS OF SEED POTATOES EXAMINED FOR FUSARIUM IN 1944.

SEED SOURCE	VARIETY AND NUMBER OF CARS						
	Chippewa	Green Mountain	Irish Cobbler	Katahdin	Earlaine No. 2	Warba	Houma
Maine	5	36	13	2	1	1	1
New York	7	16	2	—	—	—	—
Vermont	—	2	—		—		—
New Brunswick	—	1	1		—	—	—
Prince Edward Island	—	2	2	—	-	—	—

In only two cars were diseased tubers found. Isolations from these yielded *Fusarium coeruleum* and *F. sambucinum* f. *6*. Later in the season, however, seed piece decay was found present in fields planted from several of these seed sources. Five cars from one source in which no diseased tubers were found were included in this survey. In spite of this there were several cases of severe seed piece decay in fields planted with this seed.

In 1945, no organized survey of seed stock was carried on. In response to complaints from growers a number of lots were examined in storage and found to contain tubers showing typical Fusarium dry rot. These lots included seed from New York, Maine, and Prince Edward Island, Canada. The percentage of diseased tubers found in these varied from 2 to 46. Isolations made from diseased tubers showed the causal organism to be *F. sambucinum* f. *6* in the great majority of cases, although *F. coeruleum* was isolated in a few instances. It is interesting to note in this connection that in 1945 *F. sambucinum* f. *6* was of minor importance in seed piece decay on Long Island as revealed by isolations made from diseased seed pieces taken from fields. The species most commonly isolated from these fields was *F. coeruleum*.

The fact that seed piece decay developed in lots of potatoes which contained no diseased tubers suggested that the organism responsible

might be carried on the surface of the tuber or in soil adhering to the tuber. Perfectly healthy tubers from lots in which seed decay was known to have developed were washed in sterile water, the liquid centrifuged, and the sediment examined under a microscope. Fusarium spores were found to be present in abundance. Both *F. coeruleum* and *F. sambucinum* f. *6* were isolated from tubers in this manner. Seed pieces inoculated with sediment or with the uncentrifuged liquid developed typical decay of the Fusarium type and the same organisms have been recovered from diseased tissues as were found in the sediment.

On Long Island, burlap bags are probably the most widely used container in which to store potato seed pieces after they are cut. The possibility of these serving as a source of infection has been studied to a limited extent. Seed pieces cut from surface-sterilized Green Mountain potatoes were placed in sacks and then stored under conditions known to be favorable for infection. The result is shown in Table 6.

TABLE 6.—UNSTERILIZED BURLAP BAGS AS A SOURCE OF FUSARIUM INFECTION OF POTATO SEED PIECES.

SOURCE OF BAG	NUMBER OF SEED PIECES	NUMBER INFECTED	PERCENTAGE INFECTION
New York	127	94	76
Prince Edward Island	138	64	46
Long Island	130	57	44
Bag sterilized	125	0	0

Both *F. coeruleum* and *F. sambucinum* f. *6* were isolated from these lots. The bags used, with the exception of those from Long Island, were taken from lots of seed potatoes in storage for the 1946 crop. The Long Island bag was one which had been used in harvesting potatoes in the field in 1945 and in which potatoes were stored during the winter of 1945-46. From the data given it is evident that heavy infection may be obtained when burlap bags are used as storage containers, not only from bags shipped in from outside sources and containing seed potatoes, but also by the use of bags used for harvesting and storing potatoes locally. Where sterilized bags were used for storage, no infection took place. That containers may be a source of infection with *F. coeruleum* has previously been shown by Small (8) who found that injured tubers became infected from contaminated containers.

METHOD OF ENTRANCE

Repeated attempts have been made to secure infection of uninjured tubers with species of Fusarium causing seed piece decay, but the result always has been negative. Three different experiments were carried on in which diseased tubers were mixed with uninjured tubers and stored for 3 months in ordinary farm storage (35° to 40°F). In all three cases the fungus continued to grow within the infected tuber, spores were produced in abundance, but none of the uninjured tubers showed the slightest evidence of infection. Similarly, a number of experiments have been made by inoculating the unbroken surface of healthy tubers of different varieties with spore suspensions of *Fusarium coeruleum* and *F. sambucinum* f. *6* in water, smears from tube cultures, and with infested soil. In none of this work did a single tuber become infected. On the other hand, infection readily occurred in similar tests where the tubers were injured by bruising, cutting, or scraping. In view of what has been said, it would seem that the surface of the tuber must be injured in some way before the Fusarium can gain entrance. Similar experiments were carried on with seed pieces which had developed a wound cork beneath the cut surface, and it was found that this wound cork formed a natural barrier to infection by Fusarium.

CONTROL INVESTIGATIONS

Very early in the course of these studies it was found that seed treatment with some form of mercury would greatly reduce the percentage of infected seed pieces cut from stock known to carry Fusarium. These studies were enlarged to determine the best means of control.

Laboratory studies.—Germination tests have shown that spores of *Fusarium coeruleum*, *F. sambucinum* f. *6*, and *F. solani* v. *striatum* will not germinate in hanging drop cultures of either yellow oxide of mercury or Semesan Bel when used at the strength recommended for potato seed treatment. Later work has shown that Dithane (D 14),[2] when used at a strength of 1 part to 200 parts of water, will prohibit spore germination. Preliminary seed treatment work with this material has been promising. Other organic materials also are being studied in this connection, but no data are available at present on this phase of the study.

[2]Disodium ethylene bisdithiocarbamate hexahydrate.

Field studies.—The effect of seed treatment for control of Fusarium seed piece decay in relation to stand and yield is shown in Tables 7 to 11. In all of the field experiments reported in the tables, seed stock was used which was known to be free from Fusarium. This was determined in both laboratory and field tests. Any reduction in stand, therefore, may be directly attributed to Fusarium seed piece decay resulting from inoculations. In all cases, except where noted in the tables, whole tubers were treated.

TABLE 7.—SEED TREATMENT FOR THE CONTROL OF FUSARIUM SEED PIECE DECAY AS AFFECTING STAND AND YIELD OF GREEN MOUNTAIN POTATOES INOCULATED WITH *F. sambucinum* f. *6*.*

TREATMENT	AVERAGE STAND†	YIELD, BUS. PER ACRE	
		Total	No. 1
Not treated	21.5	216	178
Yellow oxide mercury, 1–30	24.7	255	222
Yellow oxide mercury, 1–30‡	25.4	256	217
Yellow oxide mercury, 1–60	24.6	207	180
Yellow oxide mercury, 1–60‡	25.9	254	220
Semesan Bel, 1–7½	22.6	223	201
Semesan Bel, 1–7½‡	25.0	262	226
L.D. (19:1) Stand: 1.9 Total: 34.3 No. 1: 33.5			

*Planted April 16, 1943.
†Average of 8 replications, 26 seed pieces in each.
‡Seed pieces inoculated and treated after cutting.

In January 1943, a number of tubers were inoculated with a spore suspension from a pure culture of *F. sambucinum* f. *6*. These were held in storage until the latter part of March. All of the tubers were infected and spores were present. Three weeks previous to planting these diseased tubers were cut into small pieces and placed in sterile bags with healthy whole tubers. The bags were then rolled about to insure thorough mixing and distribution of spores. Following this inoculation the seed potatoes were divided into lots for the purpose of applying the various treatments and all diseased pieces used for inoculation were removed.

In addition to inoculating uncut tubers, three lots were cut and the seed pieces were inoculated in the same manner as were the tubers. Where this was done the sections cut from diseased tubers were marked with India ink to facilitate their removal before treatment. The results of this test are presented in Table 7.

In this experiment 70 per cent of the seed pieces cut from inoculated untreated tubers showed evidence of seed piece decay at planting time. Many of these infected seed pieces produced plants and the final average stand for untreated seed was 21.5, or 83 per cent.

In general, seed treatment resulted in a better stand and increased yield. Treatment of whole tubers with yellow oxide of mercury, 1 pound to 60 gallons of water, and Semesan Bel, 1 pound to 7½ gallons of water, was less effective in relation to both stand and yield than was yellow oxide of mercury, 1 pound to 30 gallons of water, but this difference has not been apparent in later experiments. Treatment of cut seed pieces resulted in a better stand and larger yield with all of the materials used, but it has been found that treated seed pieces do not keep well in storage and the practice is not recommended.

In 1944, two field experiments were carried on, one in which inoculations were made in the same manner as in 1943 with portions of tubers previously inoculated with *F. sambucinum* f. *6* (Table 8). In the second experiment inoculations were made in the same way using *F. coeruleum* (Table 9), but the material used for this purpose was taken from a lot of seed pieces which carried a very heavy mass of spores on the cut surface.

TABLE 8.—SEED TREATMENT FOR THE CONTROL OF FUSARIUM SEED PIECE DECAY AS AFFECTING STAND AND YIELD OF GREEN MOUNTAIN POTATOES INOCULATED WITH *F. sambucinum* f. *6*.*

TREATMENT	SHALLOW PLANTING			DEEP PLANTING		
	Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre	
		Total	No. 1		Total	No. 1
Not treated	25.5	138	102	25.5	150	111
Yellow oxide mercury, 1–30	26.0	137	101	25.7	150	109
Yellow oxide mercury, 1–30‡	25.7	122	88	25.7	142	110
Yellow oxide mercury, 1–60	25.7	145	113	26.0	173	135
Yellow oxide mercury, 1–60‡	25.0	98	77	25.5	137	114
Semesan Bel, 1–7½	26.0	142	105	26.0	165	128
Semesan Bel, 1–7½‡	25.5	121	88	25.7	140	105
	L.D. (19:1) Stand: 0.5 Total: 58.7 No. 1: 50.1			L.D. (19:1) Stand: 0.5 Total: 44.8 No. 1: 46.9		

*Planted April 7, 1944.
†Average of 8 replications, 26 seed pieces in each.
‡Seed pieces inoculated and treated after cutting.

TABLE 9.—SEED TREATMENT FOR THE CONTROL OF FUSARIUM SEED PIECE DECAY AS AFFECTING STAND AND YIELD OF GREEN MOUNTAIN POTATOES INOCULATED WITH *F. coeruleum*.*

TREATMENT	SHALLOW PLANTING			DEEP PLANTING		
	Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre	
		Total	No. 1		Total	No. 1
Not treated	3.4	15	13	1.5	6	6
Yellow oxide mercury, 1–30	5.2	23	20	5.7	25	22
Yellow oxide mercury, 1–30‡	12.2	59	46	7.9	44	35
Yellow oxide mercury, 1–60	4.2	11	8	8.6	13	11
Yellow oxide mercury, 1–60‡	15.1	78	56	13.7	69	53
Semesan Bel, 1–7½	13.7	73	51	10.2	56	41
Semesan Bel, 1–7½‡	21.4	112	83	20.0	97	76
	L.D. (19:1) Stand: 2.5 Total: 20.4 No. 1: 21.0			L.D. (19:1) Stand: 2.5 Total: 18.6 No. 1: 16.4		

*Planted April 27, 1944.
†Average of 8 replications, 26 seed pieces in each.
‡Seed pieces inoculated and treated after cutting.

The season of 1944 was an extremely dry one and potato yields in general were far below the average. This was particularly true with potatoes planted late in the season. The soil in which the 1944 experiments were planted is much heavier than the average Long Island soil and with the continued dry weather it became so hard that many plants failed to emerge (Table 9) and many that did made little growth.

When the first planting was made on April 7 (Table 8), 20 per cent of the seed pieces cut from untreated tubers inoculated with *F. sambucinum* f. *6* showed external evidence of Fusarium infection. None was noticeable in the treated lots. Infected seed pieces eventually rotted but not before the plants became well established and as a result the stand was good with both untreated and treated seed. The yields were variable and bore little relation to either stand or Fusarium infection. Soil and seasonal conditions are the main factors influencing yield in this experiment. Altho the data given in Table 8 show no benefit from seed treatment, it was evident from the appearance of the seed pieces at planting time that treatment had prevented infection.

The second planting was made on April 27 (Table 9). The seed

pieces cut from untreated tubers inoculated with *F. coeruleum* were found to be 100 per cent infected with Fusarium, but again there was no evidence of infection in the treated lots. This was checked in the field during the season, when it was apparent that many plants were not breaking ground even in the treated plots where no infection was noticeable in the seed pieces at planting time. All seed pieces in the untreated plots rotted, altho a few plants became established before the seed piece was completely gone. In the treated plots, the seed pieces remained sound, but the stand was far from being perfect. All of the seed pieces sprouted, but the sprout in many cases remained dormant after it reached the surface of the soil. This was a soil and seasonal condition in no way related either to treatment or Fusarium infection. Altho the stand and yield bear little relation to treatment as a whole, the untreated plots in some cases did not contain a single plant (Fig. 7). In this experiment seed treatment was far more effective in controlling Fusarium than is apparent in the data given in the table.

Depth of planting had some effect on stand in plots planted with infected seed pieces. Both stand and yield were lower with the deeper planting, but for all practicable purposes the difference was negligible.

FIG. 7.—EXPERIMENTAL FIELD PLOTS AT THE LONG ISLAND VEGETABLE RESEARCH FARM, RIVERHEAD, SHOWING THE EFFECT OF SEED TREATMENT IN THE CONTROL OF FUSARIUM SEED PIECE DECAY.

All tubers inoculated with *F. coeruleum* before treatment. Inoculated untreated plot in center foreground. Rows on right treated with yellow oxide of mercury. Rows on left treated with Semesan Bel. Rows in rear uninoculated and untreated. Photographed on June 20, 1944.

In 1945, field experiments were conducted using the three different species of Fusarium which were originally isolated from decaying seed pieces taken from potato fields. The three species were used with the idea of obtaining data on their comparative virulence under field conditions and their response to control measures. Inoculation of both tubers and seed pieces was done with spore suspensions in water made from pure cultures and applied with a spray gun. Following inoculation, the tubers or seed pieces were allowed to dry, after which the various treatments for control were applied. Where the tubers were treated, they were allowed to dry before cutting. After the seed pieces were cut they were divided into two lots. One lot was kept at 40° to 50°F for ten days and an additional 10 days at 60° to 70°F (low to high, Table 11). The second lot was kept thruout the 20-day period at 60° to 70°F (high, Table 10).

Under the conditions of the experiment, neither *Fusarium sambucinum* f. *6* nor *F. solani* v. *striatum* were responsible for any appreciable reduction in stand regardless of the conditions under which the seed pieces were kept. With *F. coeruleum*, however, the stand was markedly reduced under both conditions of storage. Seed kept at 60° to 70°F thruout gave a slightly poorer stand than did that kept at 40° to 50°F for the first 10 days and then stored at 60° to 70°F until planted.

In 1945, the yields are more in keeping with the stand (Tables 10 and 11). With the exception of the lot treated with Cerumel C. (a wax emulsion) and kept at the lower temperature during the early period of storage, none of the seed stock inoculated with *F. sambucinum* f. *6* showed any evidence of seed piece decay under either of the conditions of storage after cutting. Any differences in yield in this phase of the experiment must be due to factors other than Fusarium, with exception of seed treated with Cerumel C. The stand on these plots was fair but a large percentage of the seed pieces were infected with Fusarium and the yield was reduced.

The story is much the same where the seed stock was inoculated with *F. solani* v. *striatum*. Seed piece decay was of no consequence even in untreated stock but did develop in lots treated with Cerumel C., particularly when storage temperatures were low at the beginning. This infection seriously reduced both stand and yield. Just why infection with this normally weak parasite takes place following treatment with Cerumel C. is not known, but apparently it creates a condition favoring infection.

TABLE 10.—SEED TREATMENT FOR THE CONTROL OF FUSARIUM SEED PIECE DECAY AS AFFECTING STAND AND YIELD OF GREEN MOUNTAIN POTATOES HELD FOR 20 DAYS AT 60° TO 70°F.*

TREATMENT	*F. sambucinum* f. 6			*F. coeruleum*			*F. solani* v. *striatum*		
	Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre	
		Total	No. 1		Total	No. 1		Total	No. 1
Not treated	21.5	385	324	16.6	204	174	22.9	397	335
Yellow oxide mercury, 1–30‡	22.2	395	345	23.0	350	298	22.9	431	366
Yellow oxide mercury, 1–60§	22.9	370	317	22.7	344	303	23.0	407	327
Semesan Bel, 1 7½¶	22.7	345	289	23.0	390	335	23.0	410	334
Dithane, 1–200‖	21.2	277	225	22.9	357	298	22.9	416	348
Dithane, 1–200**	22.4	398	331	18.0	321	285	22.7	427	352
Cerumel C., 1–7††**	22.2	364	302	6.1	97	85	19.2	341	297
	L.D. (19:1) Stand 1.1 Total 32.6 No. 1 47.3			L.D. (19:1) Stand 1.4 Total 49.1 No. 1 43.6			L.D. (19:1) Stand 1.1 Total 41.2 No. 1 40.2		

*Planted April 14, 1945.
†Average of 8 replications, 23 seed pieces in each.
‡1 pound to 30 gallons of water.
§1 pound to 60 gallons of water.
¶1 pound to 7½ gallons of water.
‖1 part to 200 parts of water (2 quarts in 100 gals.).
††1 part to 7 parts of water.
**In these lots both inoculation and treatment were applied to the seed pieces immediately after cutting; in the other lots, both inoculation and treatment were applied to the tubers before they were cut.

TABLE 11. SEED TREATMENT FOR THE CONTROL OF FUSARIUM SEED PIECE DECAY AS AFFECTING STAND AND YIELD OF GREEN MOUNTAIN POTATOES HELD FOR 10 DAYS AT 40° TO 50°F FOLLOWED BY 10 DAYS AT 60° TO 70°F.*

TREATMENT	*F. sambucinum* f. 6			*F. coeruleum*			*F. solani* v. *striatum*		
	Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre		Average stand†	Yield, bus. per acre	
		Total	No. 1		Total	No. 1		Total	No. 1
Not treated	22.6	381	337	17.5	209	182	21.7	367	306
Yellow oxide mercury, 1–30‡	23.0	392	336	22.7	365	307	23.0	412	337
Yellow oxide mercury, 1–60§	23.0	329	289	22.7	407	333	22.9	389	317
Semesan Bel, 1–7½¶	22.7	342	310	23.0	383	324	22.9	396	329
Dithane, 1–200‖	22.7	315	278	22.9	385	329	23.0	385	299
Dithane, 1–200**	22.7	397	349	22.2	378	326	23.0	394	309
Cerumel C., 1–7††**	21.9	246	209	9.6	132	114	12.7	182	161
	L.D. (19:1) Stand: 0.7 Total: 41.7 No. 1: 40.5			L.D. (19:1) Stand: 1.4 Total: 33.8 No. 1: 38.3			L.D. (19:1) Stand: 1.0 Total: 37.8 No. 1: 43.2		

*Planted April 14, 1945.
†Average of 8 replications, 23 seed pieces in each.
‡1 pound to 30 gallons of water.
§1 pound to 60 gallons of water.
¶1 pound to 7½ gallons of water.
‖1 part to 200 parts of water (2 quarts in 100 gals.).
††1 part to 7 parts of water.
**In these lots both inoculation and treatment were applied to the seed pieces immediately after cutting; in the other lots, both inoculation and treatment were applied to the tubers before they were cut.

Inoculation with *F. coeruleum* seriously reduced both stand and yield in the untreated plots regardless of how the seed was stored. This condition was aggravated by treatment with Cerumel C. All of the other treatments used were effective in controlling Fusarium seed piece decay.

These experiments showed that *F. coeruleum* was more virulent than the other two species. They also show that seed treatment with yellow oxide of mercury, Semesan Bel, or Dithane will control Fusarium seed piece decay.

DISCUSSION

Fusarium seed piece decay is responsible for many of the poor stands occurring in potato fields on Long Island. Our investigations have identified the causal organisms, and shown that they may be carried on the surface of the seed as well as in rotted tubers. Also, they may be present in seed stocks shipped in from all of the seed-producing areas supplying Long Island potato growers.

In the early phases of this work *Fusarium sambucinum* f. *6* appeared to be the main species responsible for seed piece decay. Later work has shown that decay may also be caused by *F. coeruleum*. In fact, in 1945, the latter species was by far the most predominant and most destructive of any of the species of Fusarium so far encountered. It is possible that the relative prevalence of different species varies from year to year. The reason for this is not known at the present time. It may be due to seasonal conditions in the seed-producing areas, to seasonal conditions on Long Island, or to both. In all probability, weather conditions in the seed-producing areas at the time the tubers are harvested may be a factor in the problem; not so much as it affects the various species, but from the standpoint of contamination of seed stock. During these investigations, it has been observed many times that more trouble is experienced with seed stocks which are dirty than with seed stocks which are clean. This may be a matter of moisture content of the soil at digging time or because of the character of the soil. Again, certain soil types may be more favorable for the growth of one Fusarium species as opposed to another.

A number of other species of Fusarium isolated from potatoes were studied. They included the following: *F. solani* v. *striatum*, *F. solani* (strain), *F. oxysporum* (strain), *F. culmorum*, and *F. avenaceum*. None were found to cause field seed piece decay. *F. solani* v.

striatum and *F. solani* (strain) were found to be capable of producing a storage rot. Since *F. solani* v. *striatum* is closely allied to *F. coeruleum*, it was used as a check fungus in a number of the test field plantings. In these tests, it never produced a serious seed piece decay.

The planting of infected seed pieces and the subsequent stand will depend upon several factors. If infected seed pieces are held in storage for any length of time previous to planting, the seed pieces may become partially rotted and the stand is likely to be seriously reduced. While no definite data are available on this point, observation would indicate that temperatures prevailing following planting are important in affecting the rate of seed piece decay in the soil. The higher the temperature, the faster the organism will penetrate the tissue and the faster will the seed piece disintegrate. The size of the seed piece and the point of infection in relation to the eye also will affect the stand. It stands to reason that a small seed piece, if infected, will decay more rapidly than will a large seed piece under the same conditions. If the point of infection is away from the eye and if the soil temperature is low, it will be some time before the seed piece is entirely decayed. In that event, the root system of the plant may become established and it is able to survive, altho it seldom makes a normal growth. If the point of infection is at or near the eye there is little possibility of a plant being produced.

While it is conceded that a good stand of plants is necessary for a maximum yield of potatoes, it is also essential that these plants be strong and vigorous if they are to yield heavily. It is quite possible, and in fact quite common, to have a good stand in a potato field where a large percentage of the seed pieces is affected with Fusarium rot. These plants have become established before the seed piece completely disintegrates, but usually they do not make a normal growth and the yield is lower than it should be. Undoubtedly the loss in yield sustained thru the presence of these weak plants is far greater than is recognized by the average grower.

There seems to be ample evidence that under Long Island conditions the seed pieces do not become infected in the soil after planting. In none of the field experiments during the period this work has been carried on has there been any evidence of seed piece decay in plots planted with uninoculated, untreated seed, altho the work was done on the same land for three successive years. The decay appears to be definitely limited to certain seed stocks. A grower

may have seed from several sources, all handled under the same conditions, and seed piece decay may be serious in one lot while no trace of it can be found in any of the other lots, even tho they may be planted on the same day and in the same field. Furthermore, it has been observed many times that the elapsed time between cutting and planting is important where seed piece decay develops in any given seed stock. Seed cut from such stock and planted immediately after cutting will rarely show any evidence of decay, while seed cut from the same lot and held in storage for a few days before planting may be 100 per cent infected. The longer these seed pieces are held in storage, the more seriously will they affect the stand.

On Long Island it has been the general practice, particularly with the larger growers, to cut the seed two to three weeks or even longer in advance of planting. When seed-piece-rotting fusaria were present, it was invariably found that seed piece decay was much more severe in lots cut some time in advance of planting as compared with the same seed stock cut and planted immediately. This led to the conclusion that there must be some condition under which the seed pieces are kept which favors infection. It is generally conceded that if seed is to be properly cured it must be kept for a few days at a temperature of 65° to 70°F, at high humidity, and with good air circulation. These conditions are essential to rapid suberization of the cut surface and the formation of wound cork. Priestly and Woffenden (6) say that previous experiments confirmed by their own work present strong evidence that suberization takes place only in the presence of air and that wound cork formation does not occur where there is no formation of suberin. Weiss, *et al* (9) say that suberization alone of the cell walls does not suffice to exclude pathogens of the Fusarium type and that at 6.7°C (44°F) wound cork formation is so greatly delayed that, in the absence of a direct environmental effect, there is no obstacle to infection. Our preliminary studies present evidence that wound cork provides an effective barrier against infection by fusaria.

So far, we have been unable to infect properly cured seed pieces unless the surface was bruised or injured in some way, nor have there been any reports of Fusarium seed piece decay where the seed pieces were properly handled. In the great majority of instances growers do not keep seed pieces under conditions where they will heal properly. Generally speaking, they are kept at a temperature too low for rapid suberization of the cut surface and formation of

wound cork, but probably the most common fault is placing the seed pieces in burlap bags and containers too tight to allow proper air circulation. Our investigations to date, as yet incomplete, would indicate that lack of proper aeration, regardless of temperature and humidity, favors infection by fusaria. The limited supply of air circulating thru these containers is not sufficient for proper healing of the cut surface but is sufficient for germination and growth of fusaria.

Because of the fact that spores are present either on the surface of tubers, in soil adhering to tubers, or in containers, the problem of control is one which lends itself well to seed treatment in some form. Field experiments have shown that seed treatment by the instant dip method, using either yellow oxide of mercury or Semesan Bel, will control Fusarium seed piece decay. In this connection it is interesting to note that on Long Island not a single case of seed piece decay has been reported where seed treatment was practiced. This does not mean that an occasional rotted seed piece may not be found in such fields. They have been found but invariably it has been evident that such pieces were cut from tubers infected before treatment. Seed treatment will not kill the fungus if it is already established in the tuber but acts rather as a surface cleansing and sterilizing agent. In the process of treatment much of the soil adhering to the tubers is washed off along with any spores the soil may contain. Spores still remaining on the tubers will be killed.

The question is often raised as to whether the tubers should be treated before they are cut or the seed pieces treated after cutting. In some of our work, treatment of cut seed pieces has shown slightly better control, but, in general, treatment of the tubers before cutting has been more satisfactory. From the practical standpoint alone it is preferable to treat the tubers. This will sterilize the surface of the tubers and prevent opportunity for infection of the seed pieces. Tubers can be treated whenever convenient and stored until cutting time. If treated seed pieces are to be stored they must be thoroly dried before they are placed in containers. This procedure is not necessary when tubers are treated.

Altho Fusarium seed piece decay can be controlled to a great extent by treating seed potatoes, the grower should not overlook the fact that seed treatment will not be effective if freshly cut seed pieces from treated stock are placed in containers carrying Fusarium spores. These spores will be present in soil adhering to containers

and infection may occur in this manner, even if the tubers have been treated. It is advisable to use containers in which potatoes have not been stored or handled. If such containers must be used, they should also be treated before seed pieces are placed in them. Containers may be treated with steam, by boiling, or by dipping in solutions used for treating potatoes.

If cut seed is to be stored for a time before planting, it should be handled in such a way as to insure proper and rapid healing of the cut surface as an added precaution against the invasion of organisms causing decay. Should the grower, for any reason, not wish to treat potatoes, one can only suggest that the seed be planted immediately after it is cut.

Considerable progress has been made to date on the more practical phases of this problem; however, much remains to be done. We still do not know why seed stock from certain areas is more likely to carry Fusarium than are stocks from other areas. Further work is needed on conditions governing infection with different species of Fusarium. While seed treatment is effective with the mercurials, they are far from being satisfactory because of their poisonous nature. What is badly needed is some material which will be effective in killing the spores and yet not be toxic to human beings. All of these points will be the basis of future work and are merely mentioned as a matter of interest in this report.

SUMMARY

Fusarium seed piece decay was found to be the cause of many poor stands of potatoes grown on Long Island. Numerous isolations made from decaying seed pieces taken either from storage or from the field yielded pure cultures of *Fusarium coeruleum* and *F. sambucinum* f. *6*. During the early course of the isolation and infection studies, *F. sambucinum* f. *6* seemed to be solely responsible, but later *F. coeruleum* also was found to be prevalent and to cause serious infection. In 1945, the latter organism was chiefly responsible for losses. *F. solani* v. *striatum* occasionally was isolated, but infection studies indicated that, while it may cause a rot of tubers, it apparently was not responsible for seed decay in the field. In both laboratory and field tests, pure cultures were used as the source of inoculum.

In all cases of seed piece decay investigated in the years 1942–45, inclusive, the above-mentioned fusaria were found to be the cause of decay. Stands in some instances were as low as 10 per cent, but a

good stand was not always associated with a low percentage of seed piece infection.

It was determined that these pathogens may be present on seed stock sent in from all of the chief seed sources. Isolations made from diseased tubers taken from storage and from incoming seed stocks revealed that the organism causing rotting of tubers was not necessarily the one causing seed piece decay. In 1945, the most prevalent organism found causing storage rot of tubers was *F. sambucinum* f. *6*, but *F. coeruleum* was the most prevalent species found causing field seed piece decay.

No extensive work has been done on the susceptibility of varieties to Fusarium seed piece decay. The varieties most commonly grown on Long Island, Irish Cobbler, Green Mountain, and Chippewa, are all susceptible.

Decay of potato seed pieces takes the form of a dry rot. The rotting tissue never becomes soft unless invaded by other organisms. Invaded tissue turns brown in color, and, if conditions are favorable, spores are produced in abundance on the cut surface. Infected seed pieces can not alway be detected by the appearance of the cut surface and may only be noticeable in the brownish tissue beneath.

Detailed descriptions and their reaction on certain media are given for *F. coeruleum*, *F. sambucinum* f. *6*, the two organisms thus far found to be chiefly responsible for field seed piece decay, and for *F. solani* v. *striatum*, which occasionally has been isolated and which will produce a storage rot but no serious field seed piece decay.

Germination tests showed that *F. coeruleum* germinated more rapidly at low temperatures than did either *F. sambucinum* f. *6* or *F. solani* v. *striatum*. Growth studies at various temperatures indicated that *F. sambucinum* f. *6* grew more rapidly in plate cultures than did either *F. coeruleum* or *F. solani* v. *striatum*.

It has been established that fusaria gain entrance thru wounds. Repeated efforts to secure infection by inoculation of the uninjured surface of tubers or of the cut surface of properly healed seed pieces have consistently failed. Infection readily occurs when the surface of a tuber or seed piece is injured in any way before inoculation.

The causal organism may be carried on the surface of the seed. Soil washings from healthy tubers were capable of causing infection of seed pieces. Dirt adhering to sacks in which potatoes were shipped or stored also was shown to be a source of infection.

Seed treatment by the instant dip method with either yellow

oxide of mercury at the rate of 1 pound to 30 gallons of water (1–30) or Semesan Bel at the rate of 1 pound to 7½ gallons of water (1–7½) has been found to be effective in controlling Fusarium seed piece decay. Dithane at the rate of 1 part to 200 parts of water gave promising results in one year's work.

Treatment of tubers before cutting is advised.

All contaminated containers used for storing and handling cut seed should be treated either with steam, by boiling, or by dipping in the solutions used for treating potatoes.

If seed pieces are to be held for any length of time before they are planted, they should be stored under conditions favorable to rapid healing of the cut surface. The longer infected seed is held in storage after it has been cut, the more serious will be the reduction in stand and yield.

LITERATURE CITED

1 Artschwager, E. Wound periderm formation in the potato as affected by temperature and humidity. *Jour. Agr. Res.*, **35**: *995–1000. 1927.*

2 Cassell, Robert C. Fusarium rots and other storage diseases of potatoes in New York. *Plant Disease Reporter*, **29**: *(13):337–342. 1945.*

3 ————. Vegetable and fruit storage diseases in New York: Summary of the 1944–1945 storage season. *Plant Disease Reporter*, **29**: *(18):450–463. 1945.*

4 Edson, H. A., and Shapovalov, M. Temperature relations of certain potato rot and wilt producing fungi. *Jour. Agr. Res.*, **18**: *511–524. 1920.*

5 Moore, E. S. The physiology of *Fusarium coeruleum*. *Ann. Bot.*, **38**: *137–161. 1924.*

6 Priestly, J. H., and Woffenden, L. M. The healing of wounds in potato tubers and their propagation by cut sets. *Ann. Appl. Biol.*, **10**: *96–115. 1923.*

7 Ridgeway, R. Color Standards and Color Nomenclature. *Washington, D. C. 1912.*

8 Small, T. Dry rot of potatoes (*Fusarium coeruleum* (Lib.) Sacc.): Investigations on the sources and time of infection. *Ann. Appl. Biol.*, **31**: *290–295. 1944.*

9 Weiss, F., Lauritzen, J. I., and Brierly, P. Factors in the inception and development of rot in storage potatoes. *United States Dept. Agriculture Tech. Bul. No. 62. 1928.*